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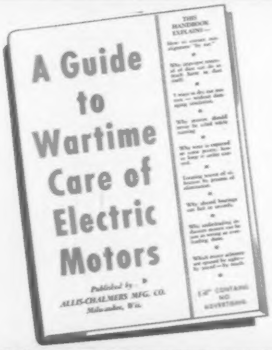

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ALLIS-CHALMERS ELECTRICAL REVIEW

C O N T E N T S

WHEN BOMBS BURST

During London's blitz, it was only through the efforts of civilian firefighters that the city was saved. Here are measures a "pioneer" plant in this country has taken in air raid precautions.

H. W. Martin

SWITCHGEAR DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● That enemy bombers should appear over our coastal and inland cities is entirely possible, if not probable. In such an event, the aim of the enemy would undoubtedly be to turn the battle of production in his favor either by direct destruction of production facilities or by reduction of civilian morale or both.

Our northeastern coastal areas are the most likely points of attack from the European end of the Axis, because they are the industrial centers nearest to Europe. Consequently, the air raid precaution organization at one of our eastern plants has been built up with a view to dealing with all possible emergencies as quickly and efficiently as possible so that any damage to machines, property, or personnel can be limited and repaired quickly enough to have the least possible effect on production. The organization, the first of its kind in its area to be completely organized, has already been in existence over a year and, in fact, was well under way before Pearl Harbor.

This ARP group is entirely voluntary, but all members are subject to call 24 hours a day. The organization is composed of nearly 100 members, or about one-sixth of the total plant personnel. All members are subject to strict discipline during drills and actual emergency.

The organization, which cooperates with the plant management, is composed of five divisions acting under a chief warden (see Fig. 1). The divisions are fire department, guards and watchmen, air raid wardens, Red Cross or first aid, and property protection (demolition, rescue, and repair). During an emergency the organization is controlled from a control center, which is in constant touch with the district report center which sends instructions to the various divisions.

AT LEFT: Military and civilian cooperation during an air raid is essential. Here a London searchlight operator hunts for Nazi planes during one of the spring raids of 1941. (H. M. Lambert photo)

Control center

The control center, centrally located, is manned 24 hours a day, and during actual emergencies or practice drills it is taken over by the nucleus of the organization consisting of the chief warden, deputy chief warden, fire chief, chief guard, Red Cross chief, and the control center clerk. The Control Center organization receives immediate reports of all happenings throughout the plant, and charts showing the location of all equipment and personnel enable it to direct the ARP organization in the most effective manner.

Fire department

An incendiary bomb weighs only two pounds; and, since an enemy bomber well-loaded with them could fly well over 3,000 miles, it is probable that, in an air raid, incendiary bombs would comprise a large part of the bomb load. Consequently, the fire-fighting division of the ARP organization is considered to be most important. The division has twenty men and is under the control of a captain and a lieutenant in addition to the fire chief. The chief and the captain of the fire division, both members of the local auxiliary fire department, are well qualified for the responsibilities of their posts. Of the twenty-odd men comprising the fire division, fifteen work on the day shift and three on each of the second and third shifts, thus insuring that at least a skeleton of the division will be immediately available at any hour of the day or night.

All buildings of the plant are adequately sprinklered and well equipped for handling an ordinary fire. In addition, a steam pump connected to a large capacity water tank is available as a reserve if the city water system breaks down. A nearby canal constitutes an almost inexhaustible last-resort reserve. Hose houses, each equipped with one hundred to two hundred feet of standard 2½ inch hose, are located close to hydrants at strategic points throughout the plant. Supplement-

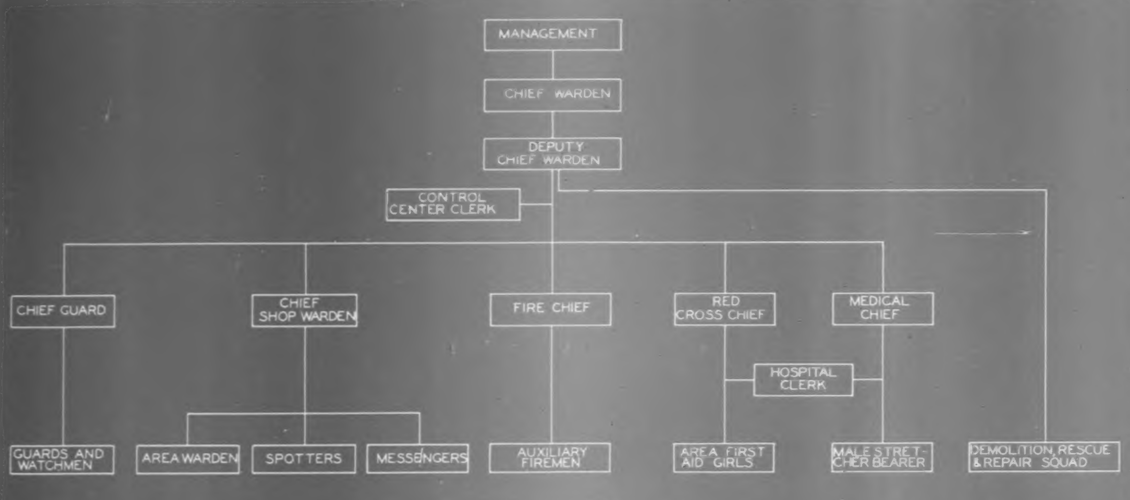


Fig. 1—ARP organization chart.

ing these are numerous firefoam and soda-acid extinguishers, and sand pails with long-handled shovels for fighting incendiary bombs are located within the buildings. Two hose wagons (Fig. 2), equipped with 2½ inch to 1½ inch Siamese fittings, shutoff play pipes, axes, bars, ropes, and salvage blankets (for protection of office equipment), complete the fire-fighting equipment.

Warden's division

The warden division, under the control of the chief shop warden, has three sections — air raid wardens, spotters, and messengers.

Each warden has had a course of training, including instruction in incendiary bomb fighting, first aid, and precautions to be taken in a poison gas attack. He is assigned to a definite area and is responsible for the personnel and property in his area. He is equipped with a helmet, auxiliary police badge, armband, flashlight, whistle, first-aid kit, and a club (for discretional use in enforcing instructions in emergency). During an emergency the area warden has complete jurisdiction over all plant personnel in his area. It is also his duty to enforce blackout regulations during night raids.

The spotters have their headquarters in a tower near the control center, and their duties are to notify the control center of approaching aircraft and patrol the factory roof for incendiary bombs. The watch tower has a direct telephone line to the control center, and one of the spotters remains in the tower throughout an emergency to notify the control center immediately of anything he sees. Each spotter wears a fireproof suit and helmet, and those who patrol the roof carry incendiary bomb scoops. Spotters are equipped to deal quickly with incendiary bombs, for in most cases they can scoop the bomb off the roof before it burns its way through into the interior of the building (Fig. 3). They thus constitute an important fire prevention organization separate from the fire fighting unit, but if necessary the fire department will assist them when so instructed by the control center clerk.

Messengers are organized to round up absent wardens by phone, bicycle, or foot and to maintain communication between the control center and the various area wardens and spotters if telephones fail. They are also responsible for contact with the local report center, police, or fire department. Messengers are equipped with helmets and with arm bands for identification, and act according to the control center clerk's instructions.

Fig. 2—Firemen answering a hose house call with one of the two hose wagons. Municipal fire department is called if necessary.

First aid division

All first aid or Red Cross section members have completed the prescribed 20-hour Red Cross first aid course, thereby qualifying as American Red Cross first aid workers. This section has twelve girls, or area first aiders, and eight male stretcher bearers. The girls are under the jurisdiction of the Red Cross chief in the control center, while the stretcher bearers are under the control of the medical chief (a registered male nurse) in the factory hospital.

Communication between the hospital and the control center is maintained by a hospital clerk who is also a qualified Red Cross instructor. All Red Cross girls are equipped with helmets, safety shoes, first aid kits, and arm bands. The men work in pairs and have helmets, arm bands, first aid kits, and stretchers.

Guards and watchmen

The guards (normally employed as watchmen) are under the direct supervision of the deputy chief warden, and their main duties are to see that no unauthorized person enters the plant and that the roadways through the grounds are kept clear of cars, trucks, and other obstacles at all times. They are equipped with helmets, badges, and clubs during emergencies. In case of a fire call, one of the guards stands by at the city fire alarm box, while others are ready to open the gates and admit the city fire apparatus.

Demolition, rescue and repair

A squad of six men, acting under the deputy chief warden, is assigned to demolition, rescue and repair. Their function is to rescue trapped personnel, tear down such sections of damaged buildings as may be hazardous to personnel if left standing, and to make temporary repairs to buildings and equipment. The squad has a mobile unit (Fig. 4) equipped with axes, shovels, jacks, ladders, rope, crowbars, sledge hammers, welding and cutting torches, chains, pulley blocks, etc. They also have available a quantity of shoring timbers for supporting shaky structures.

The organization in action

As soon as word is received at the local control center that enemy planes have been sighted approaching the coast (200 miles distant), a confidential first alert (yellow signal) is transmitted from the local control center through the main switchboard to the works manager and chief warden. If neither of these officials can be reached, the deputy chief warden is notified. The chief warden or deputy chief warden then instructs the chiefs of the various divisions to stand by, and he reports to the control center to await the second alert (blue signal), signifying that the planes are still approaching fifty miles away. After the second alert, the switchboard operator permanently connects the local control center to the plant control center,

Fig. 3 — Roof spotters in fireproof suits extinguish an incendiary bomb before it can burn its way through the roof.

Fig. 4 — The demolition, rescue, and repair mobile unit rescues trapped personnel, tears down hazardous sections, makes repairs.

and the warden's assembly signal (two long and one short blasts on the factory horns and bells) is then sounded from the control center.

Upon hearing the warden's assembly signal, the air raid wardens, messengers, and spotters don their equipment and go into action. The area wardens and their assistants immediately see that all windows are open at least six inches to minimize splintering of glass from bomb concussion and, in the case of a night raid, see that all blackout shades are effectively drawn. They then report "everything OK" to the control center.

Messengers immediately report to the control center for instructions from the control center clerk. Spotters patrol the roofs, and the spotter in the watch tower takes his position and reports to the control center as soon as the other spotters are at their stations.

Firemen assemble at station

Immediately after the wardens' assembly call has been sounded, the fire department assembly call (two short blasts repeated) is sounded, whereupon the members of the fire department assemble at the fire station and don their equipment. Some firemen are assigned to patrol the floors of the buildings, and others, equipped with ropes, man the bridges between upper floors of the buildings. As soon as the firemen have gone to their stations, the captain or lieutenant reports that everything is ready by telephone to the fire chief, who has already taken his position at the control center. The guard assigned to the city fire alarm box takes his position.

If the chief warden considers it necessary, he will also sound the first aid assembly signal (one long blast and one short blast repeated three times) after sounding the fire signal. Otherwise, the first aiders go to their posts only after the actual alarm is sounded. Area first aiders don their equipment and report to the hospital clerk immediately after they arrive at their respective areas. Stretcher bearers assemble at the hospital to get their equipment and await instructions. As soon as the first aid organization is ready for action, the hospital clerk notifies the Red Cross chief at the control center.

Production stops at last minute

When the actual air raid warning (red signal, planes 25 miles away and still approaching) is received at the control center, a series of short blasts are sounded for a period of two minutes. From then on all interdepartmental activity ceases, and persons in departments other than their own are required to stay

where they are. To cease work before this would fulfill one of the purposes of an enemy air raid — that of interfering with war production — so work proceeds until specific instructions otherwise are received from the control center.

As soon as word is received at the control center from the spotters in the watch tower that enemy planes are approaching, the chief warden or deputy chief warden will transmit such instructions as he considers necessary for the protection of the personnel (such as evacuation of the upper floors) to the area wardens. All plant personnel have been instructed in the procedure of evacuating buildings or upper floors of buildings. They have also been advised to keep away from windows and doors and to lie face down on the floor, under a desk or heavy table if possible, and to cover the back of the head and neck with a jacket or coat when instructed to do so by area wardens.

When an incendiary bomb falls on the roof, the spotters, clad in their fireproof suits, go into immediate action with their bomb scoops, while the watch tower notifies the control center where the bomb fell so that members of the fire department can be sent to assist if necessary. If the incendiaries penetrate into the upper floors of the buildings, the area wardens or patrolling firemen notify the control center. The fire department then goes into action when the hose house signal (the hose house number repeated) is sounded from the control center to assemble the firemen at the hose house nearest to the fire. The firemen on the bridges between buildings remain at their posts to hoist hose to the upper floors with their ropes. If the fire or fires get beyond the control of the plant fire department, the watchman at the city fire alarm box is ordered to put in the alarm and the watchmen at the gates stand by to admit the city fire apparatus.

Fig. 5 — Red Cross girl administers first aid to stretcher victim. This is one of the first plants in the U. S. with ARP program.

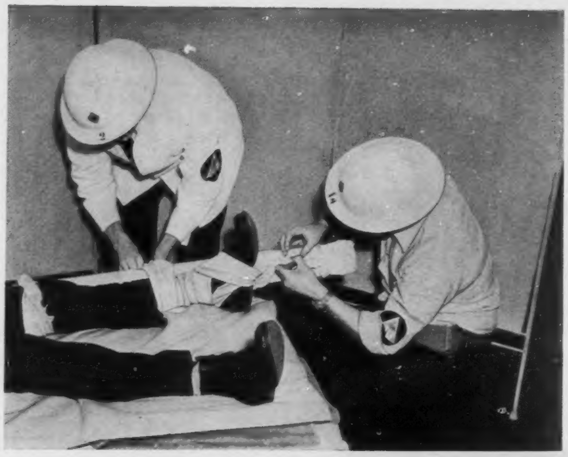


Fig. 6 — More serious injuries are attended to in the well-equipped plant hospital. All casualties are treated for shock.

First aiders treat casualties

In case high explosives are dropped on the plant or in the vicinity of the plant, casualties are likely to occur. Area first aiders with the help of the area wardens administer to the various casualties according to their seriousness and requisition stretcher bearers when necessary, by telephoning the hospital. Cases of arterial bleeding get first attention, followed by attention to unconscious persons, persons suspected of internal injuries, fracture cases, and cuts and abrasions. (See Figs. 5 and 6.) All casualties are treated for shock.

Should high-explosive damage trap personnel, the area warden or one of his assistants notifies the control center, which immediately dispatches the demolition squad with its mobile unit to extricate the victim. First aid is administered to the trapped person immediately, and stretcher bearers are requisitioned as soon as necessary. The demolition squad also repairs damaged facilities as quickly as possible to prevent further injuries from the collapsing of unsafe structures.

If gas bombs strike sections of the plant, the area wardens immediately order evacuation of the contaminated sections. Other sections of the plant evacuate or move to the upper floors according to the instructions received from the chief warden or deputy chief warden through the control center.

As soon as the all-clear is sounded (a two-minute blast), such production as has ceased during the raid is continued if conditions permit. Wardens, first aiders, and firemen then report to the control center, the hospital, or the fire station, as the case may be, as soon as conditions in their respective areas of action permit. They are dismissed, or assigned to other areas where help is needed. The demolition, rescue and repair squad remains on duty until released by the deputy chief warden.

HOW TO INCREASE CAPACITY OF OLD AND NEW TRANSFORMERS

Forced-oil and forced-air cooling dissipates power transformer losses faster, freeing critical materials for other war uses, and getting more kilowatt capacity per pound from both old and new transformers.

W. C. Sealey, **Engineer-in-Charge**

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

● Among the scarce materials necessary for the war effort are iron and copper, which are used in the construction of transformers as well as in ships and direct implements of war. Since the supply of iron and copper is definitely limited, it is imperative that new transformers be built with a minimum quantity of these critical materials and that maximum use be obtained from materials which have been previously fabricated into transformers.

A transformer with forced-oil cooling can be built with less material than any other type of transformer in common use. In parts of Europe where materials have been scarce even in normal times, most large transformers have been forced-oil cooled. In the United States, where low transformer losses and freedom from maintenance have been more important, very few transformers have been forced-oil cooled. However, now that emphasis is placed on conservation of materials, forced-oil cooling is being extensively used, both to increase the rating of old transformers and to minimize the material required for new ones.

A forced-oil cooled transformer is an oil-immersed transformer in which the oil is cooled as it is pumped through a heat exchanger. The hot oil is drawn off near the top of the tank, pumped through a heat exchanger where it is cooled and then returned through an opening near the bottom of the tank. The heat exchanger can be one of two types — where water is available, an oil-to-water heat exchanger is often used, in which case the oil flows through tubes immersed in flowing water. Since cooling water is not always available, an oil-to-air heat exchanger is the type more suitable for universal application. In this type the tubes containing the oil have cooling air forced past the tube surfaces by a fan. For maximum cooling efficiency, a large quantity of oil must be circulated and a large volume of air forced past the tubes.

Connections, stuffing boxes leaked

The first forced-oil equipment for cooling transformers consisted, naturally, of adaptations of existing pumps and heat exchangers. Fairly large pumps and heat exchangers were mounted separately or on the base of the transformer, but the cooling system was essentially a separate unit.

This construction introduced complications. The transformer and the cooling unit had to be connected together with piping, and to prevent leakage they had to be mounted on the same foundation or connected with flexible connections. Rigid piping connecting the transformer and cooling unit, when not on the same foundation, was subject to stressed joints as the foundation settled. Other disadvantages were that a heat exchanger of a different size for each transformer had to be built; and, when leakage occurred, it was necessary to shut down the complete unit to make repairs.

Because a large quantity of oil was handled at a relatively low head, a motor-driven centrifugal pump was commonly used to circulate oil. A stuffing box had to be provided for the pump shaft, and it was extremely difficult to maintain this stuffing box perfectly oil-tight. In addition, special bleeding pipes were necessary to prevent air from being drawn in through the stuffing box, and these pipes in turn increased the likelihood of oil leakage.

Unit construction with oil-immersed motor

A recent development in forced-oil cooling (Figs. 1 and 2) is a unit type construction in which the motor, pump, and heat exchanger form a single unit, mounted in the same manner as the radiator usually provided for self-cooled transformers. The motor is oil-immersed in the same casing with the pump, thereby eliminating the stuffing box. The motor is three phase and has no brushes, centrifugal switches or other devices

to cause trouble. The transformer oil flowing through the windings cools the motor and lubricates the bearings.

A centrifugal pump is used because it is particularly well adapted to handling the large quantities of oil at low heads required in this case. The pump characteristics are such that the motor will never be overloaded regardless of the resistance to oil flow. The heat exchanger is an automotive type radiator modified for greater mechanical ruggedness. A propeller type fan, which is especially suited for handling large volumes of air at low heads, is mounted on the radiator frame.

This assembly of pump and heat exchanger with the piping makes it possible to mount such an assembly on the flanges of the radiator valves as a complete unit. The unit is mounted in the same way as the radiator of a self-cooled transformer and needs no additional support. As many units as are necessary to dissipate the loss can be mounted on each transformer.

Each unit independent

Unit construction overcomes the disadvantages of conventional forced air equipment. There are no stuffing boxes or stressed pipe joints to leak oil. If one unit is damaged, the radiator valves can be closed and the unit taken out of service without affecting the operation of the remaining units.

Forced-oil cooling is the most effective means of increasing the safe load which may be carried by a given transformer core and coils. With a given ambient, the load which a transformer can safely carry is determined by the hot spot copper rise over the ambient temperature. Curve A (Fig. 3) shows the temperature difference between the copper and oil of a typical transformer. Subtracting this difference from the allowable hot spot copper rise gives Curve B, which is the permissible oil temperature rise over the ambient, for a 65 C copper rise. The oil temperature rise over the ambient temperature may be limited to the desired value by any means of cooling, such as self-cooling, water-cooling, forced-air, or forced-oil; but the means of cooling which requires the minimum of critical material is forced-oil cooling.

More oil, more air, more kilowatts

The greater the difference between the temperature of the oil flowing through the cooling tubes and the temperature of the air flowing past the cooling tubes, the greater will be the kw loss dissipated by the heat exchanger. This relation is shown in Fig. 4. The oil temperature must always be higher than the adjacent air temperature since the flow of heat is from the oil to the air.

In order to obtain a maximum difference between oil and air temperatures, both should remain as close as possible to their respective entering temperatures. The lowering of the decrease in oil temperature as the oil flow through the cooling tubes (gpm/kw of loss) increases is shown in Fig. 5. The decrease in the

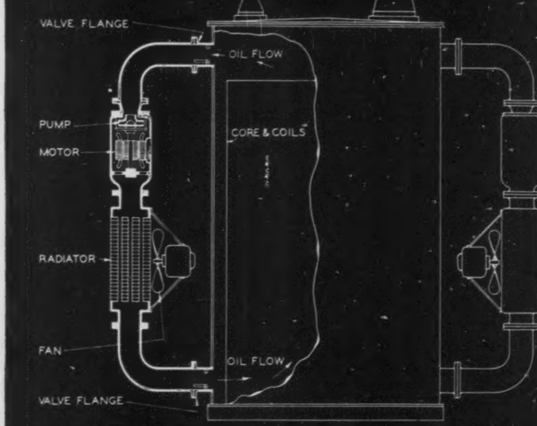


Fig. 1—Oil-immersed motor drives pump that circulates oil through an oil-air heat exchanger. Blower forces air through radiator.

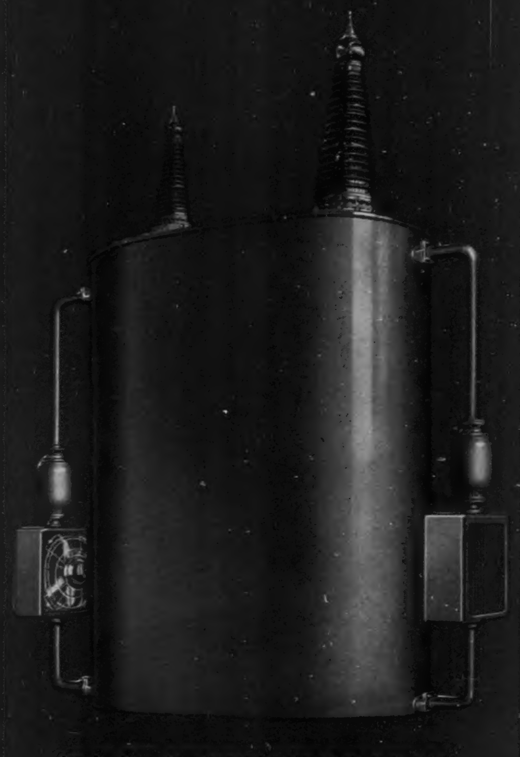


Fig. 2—New development in forced-oil cooling has motor, pump and heat exchanger mounted as a single unit like radiators on self-cooled units.

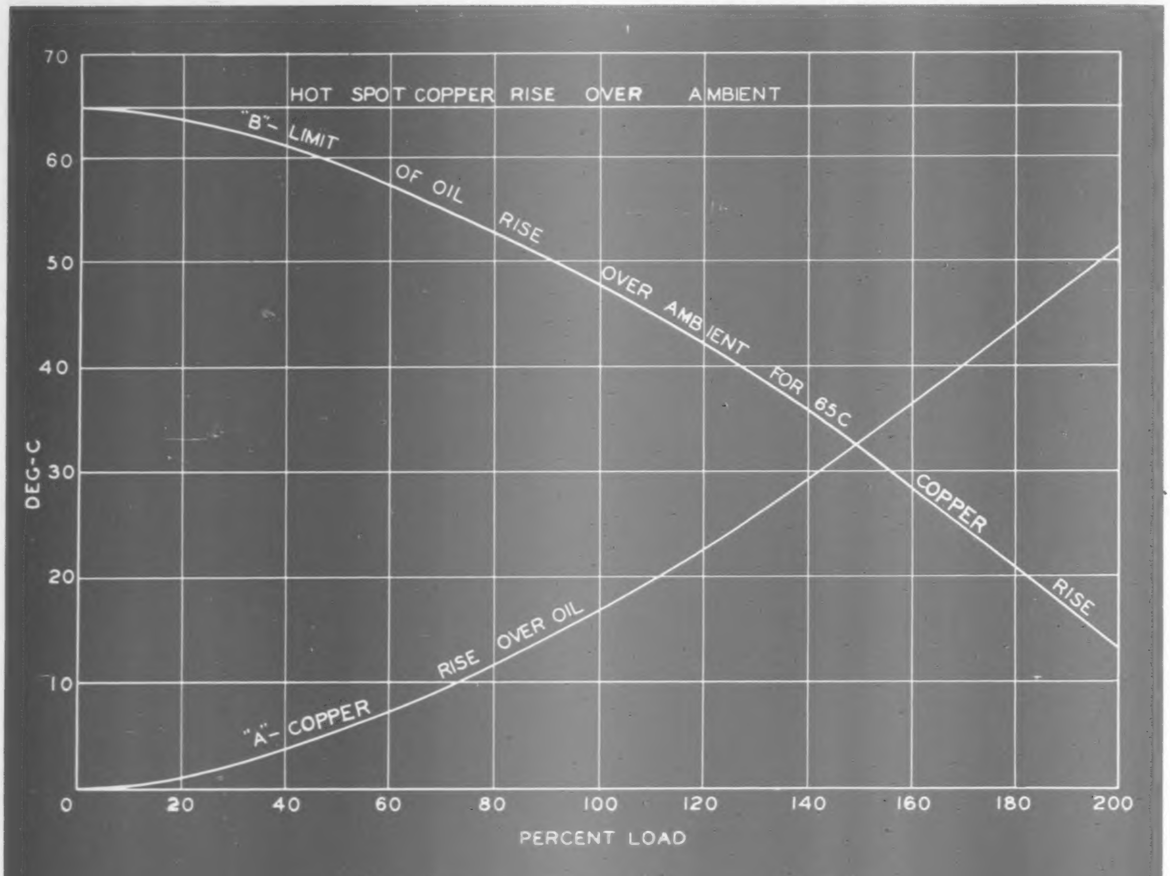


Fig. 3—Temperature difference between copper and oil.

temperature rise of the air as it flows past the cooling tubes as the cfm/kw of loss absorbed by the air increases as shown in Fig. 6.

Figure 7a shows the temperature relations with a slow rate of oil and air flow for comparison with Fig. 7b with a fast rate of oil and air flow. The flow of heat from the oil to the air at any point is proportional to the temperature difference between the oil and air at that location. Consequently, the heat dissipated is proportional to the shaded area between the two curves. Both sets of curves are drawn for the same entering oil and air temperatures. It is evident that the faster the rate of flow of oil and air, the greater will be the rate of heat dissipation.

Load transformers up to 160 percent

As shown by these curves, the gpm of oil per kw and the cfm of air per kw should be as high as practicable so that the change in oil temperature and the change in air temperature will be a small fraction of the total temperature difference between the entering oil temperature and entering air temperature. Accordingly, the principal reason forced-oil cooling is much more effective than cooling by natural convection is because the gpm of oil flow can be much greater when oil is moved by a pump and because the cfm of air per kw of loss can be greater when the air is moved by a fan.

Since in practice it is entirely feasible to secure oil rises of about 25 to 30 C, loads of approximately 160 percent of the normal self-cooled rating are often possible with forced-oil cooling, providing the bushings and other parts of the transformer are designed to withstand the overloads.

The copper losses of a transformer increase with the square of the load. Consequently, the efficiency of a transformer operating at a heavy overload is considerably lower than that of a transformer which is not overloaded. This sacrifice of efficiency occurs whenever transformers are overloaded independently of the method of cooling. During the present emergency, the increased cost of the losses is the price for saving critical materials for other purposes. In normal times when material is readily available, the decision can be made strictly on a cost basis as to which will result in a lower over-all cost — a forced-oil cooled transformer with higher losses and increased maintenance or a self-cooled transformer with lower losses, less maintenance, and higher first cost.

Future of forced-oil cooling

Forced-oil cooling increases the capacity of a transformer built with a given amount of material. The disadvantages lie in the complication of construction and in the fact that some maintenance is required for moving parts which have less continuity of service than purely static apparatus. Unit construction minimizes both of these disadvantages because the unit is simple in application and construction so that it may be mounted with the same facility as the conventional type of radiator. One unit can be taken out of operation for servicing without affecting the operation of remaining units on the transformer.

In the past, forced-oil cooling has been used mainly as an emergency type of construction in the United States. It is natural to expect that, after the present emergency, forced-oil cooling will be used to a somewhat greater extent than formerly, especially for applications where it is necessary to increase the rating of an existing bank of transformers, or where the lower first cost will offset higher cost of operation caused by increased losses and maintenance. Indications are that forced-oil cooling will never entirely supplant self-cooling, which results in maximum reliability and lowest maintenance. However, the unit type construction of forced-oil cooling not only is a solution for the saving of critical material, but it offers advantages which make its continued use probable after the war.

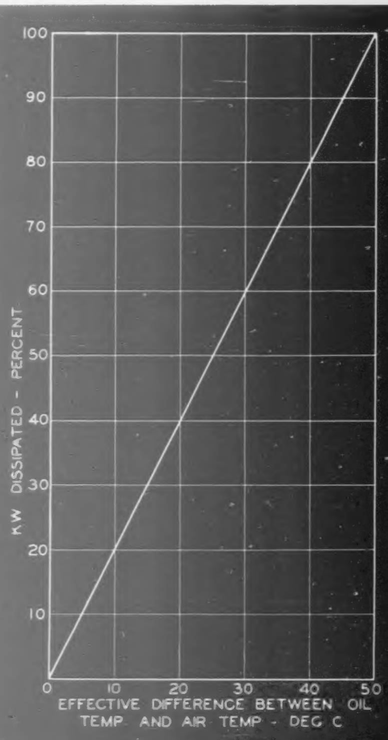


Fig. 4—Relation of heat dissipated to oil-air temp.

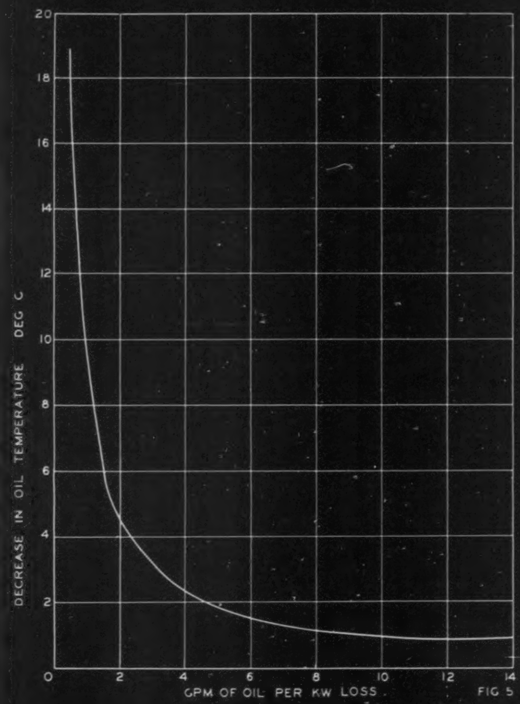


Fig. 5—Oil temperature.

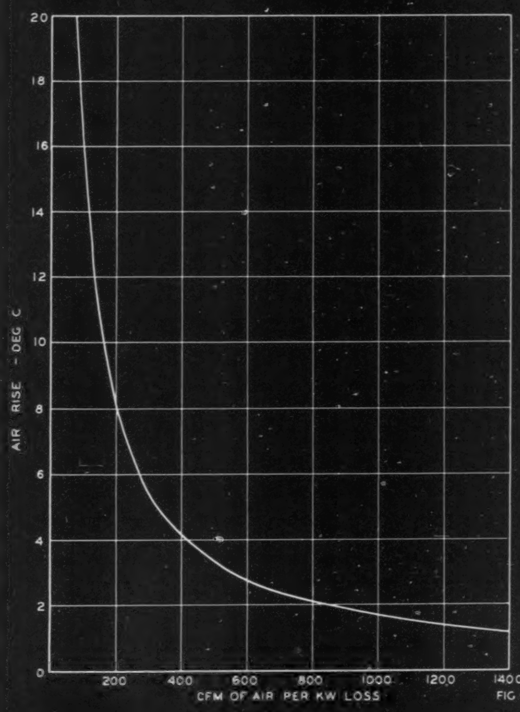


Fig. 6—Air temperature.

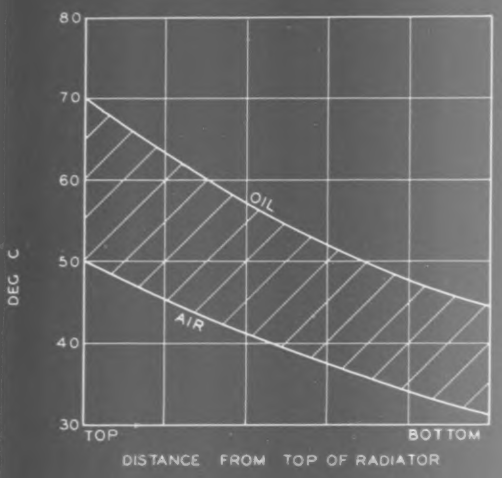


Fig. 7a—Slow rate of oil and air flow.

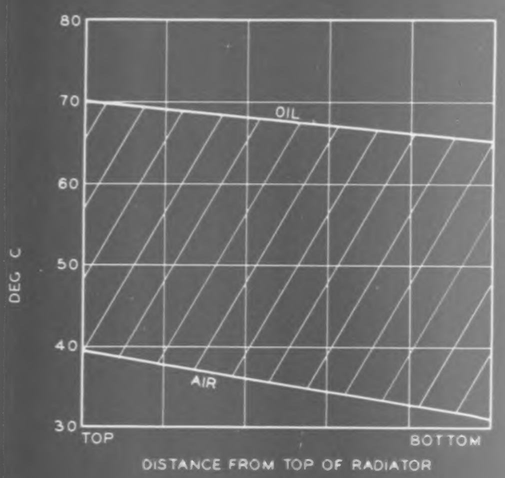
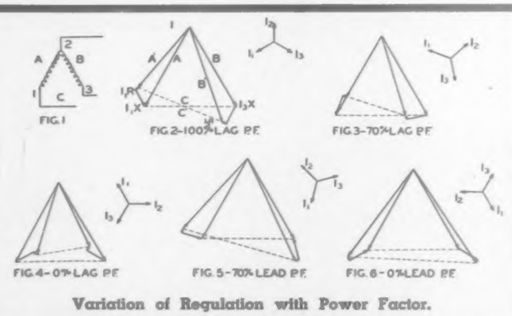


Fig. 7b—Fast rate of oil and air flow.



Variation of Regulation with Power Factor.

? WHAT'S THE ANSWER?

Question—We have a bank of three delta-connected 2500 kva transformers which are normally paralleled with a delta bank of three 1000 kva transformers. All transformers have a 4.66% impedance. One of the 2500 kva transformers has failed. How can we get the maximum capacity from the five remaining transformers while the sixth is being repaired?—B. R. S.

Answer—The transformers can be reconnected in one of several ways to get more capacity than would be available if the 2500 kva unit were merely dropped from the bank, which would result in a closed delta bank and a capacity of only 5720 kva.

(1) The three 1000 kva transformers can be paralleled to close an open delta consisting of the remaining 2500 kva units to give a total capacity of 7685 kva. Considerable rewiring would be needed.

(2) One 2500 kva transformer can be paralleled with one 1000 kva transformer for each leg of an open delta bank. This is accomplished by simply disconnecting the 1000 kva transformer which normally parallels the 2500 kva transformer that failed. Total capacity will be 6060 kva.

Question—In an open delta transformer, which phase has the best regulation?—V. G. C.

Answer—With transformer secondaries connected as shown in Fig. 1 (at left) and with a phase rotation of 1-2-3, the power factor angles in Figs. 2 to 6 are the lead or lag of the line currents with respect to the neutral voltages. Therefore, at unity power factor, the current in phase A lags voltage A, while the current in phase B leads voltage B. It is this condition of lagging and leading currents which causes the variation of regulation among the three phases.

In the diagrams A′, B′ and C′ represent the phase voltages under load, and A, B and C represent the no-load voltage with the same voltage impressed on the primary as when loaded.

Regulation $A = \frac{A - A'}{A'}$. Similarly for B and C.

The following table gives the regulations of phases A, B and C with unit values of load voltage IR and IX but different power factors.

	UNIT VALUES				% REGULATION		
	A′	B′	C′	A = B = C	A	B	C
0 Lag	.825	.775	.60	1	21.2	29.0	66.7
70% Lag	.750	.900	.675	1	33.4	11.1	48.0
100%	.850	1.100	1.00	1	17.6	— 9.1	0
70% Lead	1.050	1.25	1.30	1	— 4.76	—20.0	—23.0
0% Lead	1.20	1.25	1.40	1	—16.7	—20.0	—28.5

The most general condition is between 70% lagging and unity power factor, where phase B has the best regulation, and phase C, the open side of the delta, has the poorest regulation. However, this is not always the case because when the IR component is made larger at 70% lagging power factor, the regulation of phase A becomes best, and the regulation of phase C remains poorest.

The comparative regulation of the individual phases of an open delta transformer bank depends on the power factor of the load and the magnitude of the IR and IX drops in the transformer.

"What's the Answer?" is conducted for the benefit of readers of ELECTRICAL REVIEW who have questions on central station, industrial or power plant equipment. Send all questions to the Editors of ELECTRICAL REVIEW.

DO IT WITH SYNCHRONOUS MOTORS!

New life has been given synchronous motors by modern engineering that gives them wide torque ranges. Here are a few simple points to consider in specifying synchronous motors for specific jobs.

C. D. Lawton

ELECTRICAL DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

● A manufacturer about to purchase motors of fairly large ratings must decide upon the type of motor he requires — one that will do the job efficiently. The plant may have already had extensions, and the power distribution system may be loaded to capacity with lagging current from numerous induction motors, resulting in considerable line voltage drop, high line losses and poor general operating characteristics. Synchronous motors can provide corrective leading reactive kva which can aid materially in providing efficient operation, and they are naturally considered for the new drives. This discussion outlines general points which may influence the type of synchronous motors which can be applied to the average industrial drive.

New synchronous motors adaptable

Synchronous motors are becoming more popular as industry learns to appreciate their value as a machine that cuts power waste. No longer is the field of the synchronous motor limited by available torques because now motors can be designed to meet nearly any commercial application where a constant speed motor can be used.

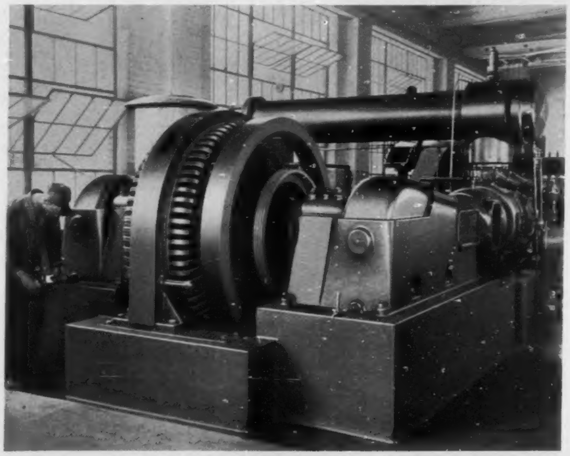
A successful synchronous motor installation requires a prior analysis of the characteristics of both load and power system. Many loads in the average manufacturing plant or processing industry are easily adaptable to synchronous motor power. Large drives over 50 hp are preferable because smaller motors are not usually economically justifiable. Usually a large plant has many such loads, but smaller plants may have only a few, such as pumps or compressors.

Synchronous motors are available for unity or leading power factor, usually 80 percent leading. The amount of leading power factor is determined by the requirements of the installation. A city pumping plant may use all unity power factor motors, while an industrial plant with numerous induction motors would require a synchronous motor with sufficient leading reactive kva capacity to bring the total plant power factor up to an economically high value.

If a synchronous motor is selected as the best way to correct the inefficiencies of low power factor, its location in the power system should be carefully planned. A synchronous motor should be strategically located in the center of a network of induction motors or other lagging power factor machines so that it supplies the leading reactive kva where necessary to avoid power waste and voltage drop in the distribution system. This is essential if the motor is also to correct for voltage drop on feeder distribution lines.

Starting torque

Starting torque is well understood, and any motor, induction or synchronous, must have enough starting torque to start the driven machine. After the load is started, the "pull-up" torque must be sufficient to bring the load up to nearly normal operating speed within reasonable time. There must be no large dips in the



Compressor requires a synchronous motor with standard torques and rotor WR^2. Flywheel compensates for 66% current pulsation.

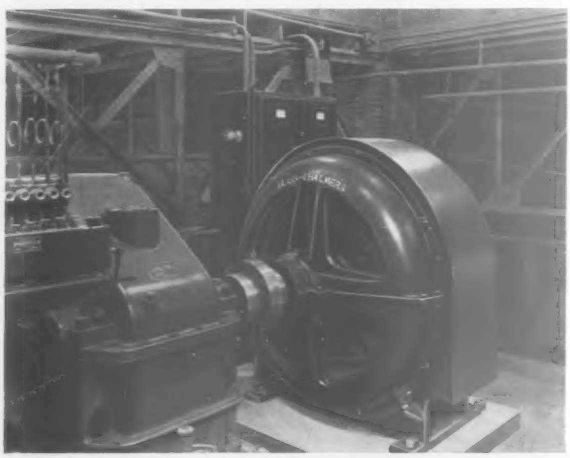
torque curve so that the motor won't "lock-in" at half speed or some other speed during acceleration. Finally, after the motor comes within 95 percent of synchronous speed, the "pull-in" torque must be enough to pull the motor and its load into synchronism.

The speed-torque characteristics of the driven load must be known so that a motor that will meet these requirements can be specified. For starting torque, it must be known whether the driven machine is started unloaded or loaded and what the static friction is. A load such as a flour mill line shaft is very hard to start, especially after a week-end shutdown during which time the oil has drained from the bearings. Such a drive may require 175 to 200 percent starting torque. Often a load like this is driven through a magnetic clutch, which allows the motor to start with no load other than its own friction and WR^2.

A motor with a high starting torque load, direct-coupled or belted to it, must be started across the line to utilize the motor's full torque, resulting in high starting kva.

Starting kva

The starting kva of a synchronous motor is not determined by the size of the load or load WR^2 but only by the inherent motor design. The starting kva of a synchronous motor is close to that of a comparable squirrel cage motor, being lower for lower speed machines and also lower in percentage for larger machines. The actual starting kva for an 80 percent power factor motor is about the same as for a unity power factor motor of the same rating and speed, but the percentage values are different, being lower for 80 percent power factor because the normal rated current is higher.



Two-speed synchronous motor drives banbury, starts on full voltage to utilize high starting torque. Load torque is high, load WR^2 low.

The duration of the starting period depends upon the load torque and the load WR^2. A motor with high starting torque, for example 160 percent, and good speed-torque characteristics will accelerate a ball mill to normal speed in eight or ten seconds; while a bandsaw mill with very high WR^2, started "light" or unloaded, may require 45 seconds to accelerate when driven by a motor with 120 percent starting torque.

Nothing is gained by using a motor with higher starting torque than necessary and starting on reduced voltage to limit the starting kva because the starting torque is reduced in approximately the same proportion as the starting kva.

Grinding mills, rubber mills, banbury mixers, beaters and some reciprocating pumps fall into the classification requiring high starting torques.

When motors are started "light," reduced voltage is often used to limit the starting kva. This method of starting, which reduces light flicker and voltage drop, is used where line disturbances cannot be tolerated. When the power system is isolated and is of limited capacity, full voltage starting is not usually used for large motors because the system voltage may drop so low that the synchronous motor could not accelerate itself, and other motors on the system might drop out of synchronism.

Where full voltage starting is used, the power system must be able to supply the required kva. Most industrial areas of the United States are fed by high-capacity power networks, which permit this form of starting. Even on these large power systems, there are districts having office buildings, laboratories, and stores where line disturbances are not usually permitted because they cause light flicker.

Pull-in torque

After a synchronous motor has accelerated to near-synchronous speed, the d-c field current is applied, and the motor pulls into synchronism.

The amount of pull-in torque that the motor must have is determined by the amount of load torque which the motor must pull into synchronism. Since high inertia loads reduce the motor pull-in torque, careful consideration must be given to the WR^2 of the load. Sometimes the driven machine is not loaded until the motor is in synchronism, as in most centrifugal pumps where the inlet or discharge valves are not opened until the motor has reached normal running speed. Some machines, such as mine fans, cannot be unloaded during starting. In such instances, the load builds up as the motor comes up to speed, and the motor must "pull in" under full load torque plus the load WR^2.

American Standards Association defines the pull-in torque of a synchronous motor as the maximum constant torque under which the motor will pull its connected inertia load into synchronism at rated voltage and frequency when its field excitation is applied. Thus pull-in torque is the actual load torque against which a motor is capable of synchronizing. It can be seen that load WR^2 materially affects the value of pull-in torque, and any guarantee of pull-in torque must include not only the torque value itself but also the load WR^2 upon which it is based.

Most industrial drives can be started with reduced load and do not have excessive load WR^2; consequently they represent no particular hardship on a motor as far as pulling-in is concerned. Others have a high WR^2, such as certain types of fans, bandsaw mills, hammer mills, and crushers, some of which must be started under full load torque. The WR^2 of these drives and their speed-torque characteristics must be given careful consideration so that the motor can be designed for the proper amount of pull-in torque.

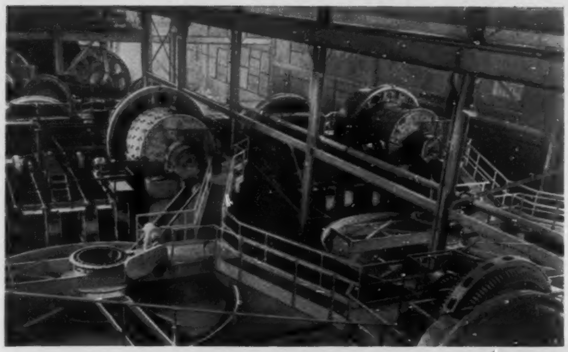
Sometimes flywheel effect is built into low speed synchronous motors used for driving reciprocating loads, such as compressors and pumps, to reduce line current pulsations. At times, particularly with reciprocating pumps, this flywheel effect is so large that higher pull-in torque must be designed into the motor to compensate for this abnormal WR^2 condition. This is especially true when a reciprocating pump is not bypassed during starting.

Pull-in torque is also affected by line voltage drop. Thus, if the line voltage is only 90 percent of normal at pull-in, the pull-in torque is reduced to 81 percent of normal; consequently, the motor must be built with enough surplus pull-in torque to compensate for low voltage condition. This is especially necessary where the load WR^2 is high and the motor must "pull in" under full load.

Pull-out torque

The normal pull-out torque for standard unity power factor motors is 150 percent and for 80 percent power factor motors at least 200 percent, these being high enough for the usual industrial load. Some loads require higher pull-out torques because of load peaks; for example, in saw mills, 250 percent pull-out torque is usually required; rubber mill drives, 225 to 250 percent pull-out torque; and crushers, as high as 300 percent pull-out torque. All motors must have pull-out torque high enough to avoid the danger of falling out of step during line voltage disturbances.

If a high starting torque is required to start loads such as line shafts or grinding mills, but the power system has not enough capacity for full voltage starting, a magnetic clutch may be used to permit starting the motor "light"; i. e., disconnected from the load. The "pull-out" torque must then be at least 175 percent to prevent the motor from pulling out of synchronism when the clutch is engaged.



Synchronous motors with high starting torque accelerate grinding mills in 8 to 10 seconds. Load torque is high, load WR^2 moderate.

Overload

Sometimes a motor built with higher than normal starting and pull-in torques may not reach rated temperature rise when carrying normal load, and there is a tendency among some operators to load them beyond their nameplate rating because it is sometimes thought that heating alone limits the load a motor can carry. When a motor is loaded beyond its nameplate rating, the percent starting and pull-in torques are reduced by the percentage of overload. This reduction in torques may in some cases give trouble in starting and pulling-in even though the motor would operate within its rated temperature rise.

Synchronous motors rated 40 C rise have a 15 percent service factor where the ambient temperature does not exceed 40 C, meaning that the motor can carry 15 percent overload continuously without dangerous heating. However, the torques must be considered if overloaded operation is to be attempted.

Further considerations

Excitation may also be a problem. Shop d-c supplies of 125 or 250 volts are common and may be used as a source of excitation. Usually synchronous motors are equipped with direct-connected or belted exciters or exciter m-g sets.

In general, the application of synchronous motors requires a little more thought than other motors because the additional consideration of pull-in torque requires a thorough analysis of load-torque characteristics, load WR^2, and operating conditions.

ON FOLLOWING PAGES: On test, this flywheel set will support an aluminum plant blooming mill. Motor is rated 4,000 hp, generators are 2,000 kw each. Flywheel is being balanced.

MOVING FREIGHT WHERE IT'S NEEDED ... FAST!

More and bigger heavy machinery, plus special wartime cargoes, eat up the nation's supply of special freight cars. But co-operation between railroads and shippers, seasoned by traffic managers' ingenuity, has eased this "transportation bottleneck."

Ervin Manske, **Manager**

TRAFFIC DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

● "Conditions are such that even now railroad motive power is being used close to capacity. . . . The normal peak load comes in the fall and is followed by unfavorable winter conditions. War production and traffic movement will continue to increase. So will troop movements." — *From General Order No. 18, issued by Joseph B. Eastman, Director of Defense Transportation, ordering the maximum loading of freight cars, with certain exceptions.*

Traffic managers today are barricading themselves behind the "Railroad Equipment Register," the "Clearance Guide," and several million more cubic feet of data. They're getting set for another winter offensive. Everyone has heard of the "transportation bottleneck," but most people just go back to work and hope it comes out all right. On the other hand, the traffic manager's biggest job right now is the "transportation bottleneck."

One day he gets his cars lined up for the next day's load, goes to bed tired but happy. The next morning he learns the cars have been requisitioned by the Government during the night, "destination unknown." Then he starts all over, because the Government needs those cars more than he does.

Even during peace, troubles

In normal times the traffic manager's problems are big enough. Suppose his company gets an order for a turbine-driven generator. Before construction is started, blueprints of the largest pieces must be sent to the traffic department to see if a route is available over which these pieces will clear the railroad right-of-ways and obstructions.

For pieces over 18 feet high, ordinary cars are out of the question. A survey is made of available depressed-center, well, and open pit cars to determine which ones will give the most clearance. The route is chosen from the "Clearance Guide," which gives the clearances of the different roads, and the car is chosen from the "Railroad Equipment Register." Then the engineering department can be told to build accordingly. If the design and dimensions are changed for manufacturing or engineering reasons, the whole procedure has to be repeated.

But now two years have elapsed in which the generator has been finished and is badly needed at its destination. However, two months ago the Navy requisitioned every one of this particular type of car, of which there are only a few, for transporting gun slides. Furthermore, the Navy will have the cars for one or two years. Then, if the generator is going to be installed so the power can be used in war work, it's the traffic manager who has to get the machine to its site.

This is no isolated example. Big machines are increasing in size and quantity, and a plant that makes turbines, generators, and transformers needs depressed-center or transformer cars constantly. As can be seen in Fig. 1, three of the six cars in which hydraulic turbine casings were shipped to Boulder Dam were depressed-center cars. Incidentally, these pieces were so large that their clearance uncertainty made it necessary to move them only by daylight.

A whole world of special problems revolves around the necessity of keeping these cars available. Traffic managers have to see to it that such cars are promptly unloaded at destination and sent back to the factory without delay. For example, there are only ten transformer cars owned by railroads operating in the midwest, and it is quite a traffic job to schedule heavy equipment and cars. Accurate records are kept of when a car leaves the plant, when it reaches each carrier, when the customer gets it, and when it gets back to the factory. Responsible people at each of those points must be made fully aware of the urgency of prompt return, so that not a day is lost.

Fig. 1—Six cast steel casing sections for the first of six 115,000 hp hydraulic turbines ready for shipment to Boulder Dam. Three of the six cars have depressed centers.

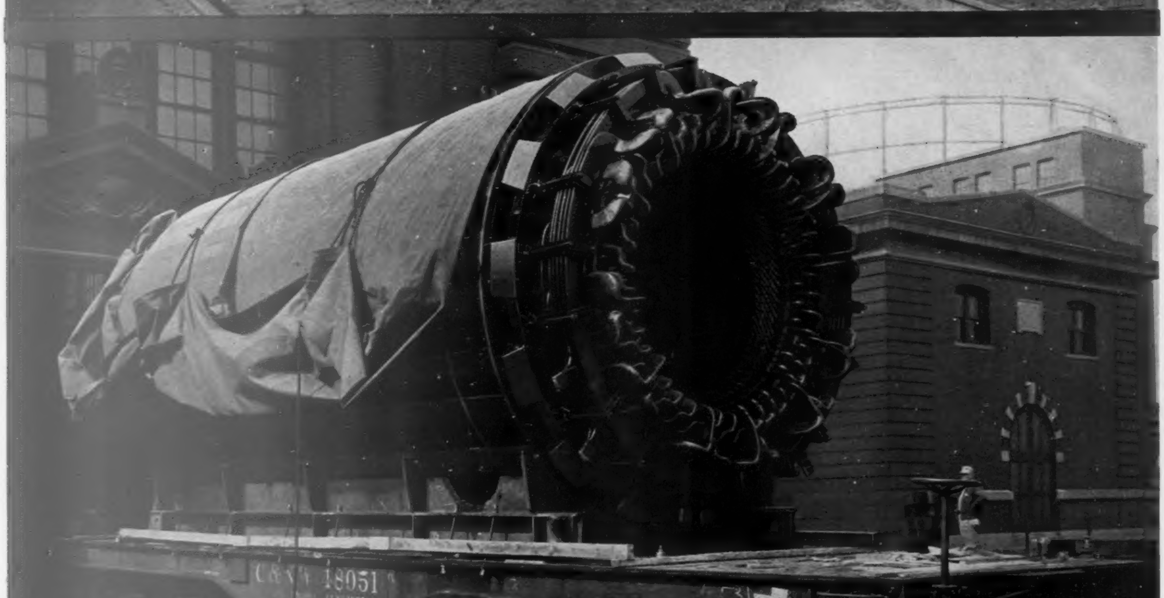


Fig. 2—This stator for a 147,000 kw turbo-generator (one of the largest ever built) exceeded weight capacity by 82,000 pounds, but special handling permitted shipment.

Fig. 3—Depressed-center cars are used to gain height. But even using them, these transformers had to be routed 400 miles out of the way to get needed clearance.

Fig. 4—Extremely long pieces of equipment that must be shipped in one piece present another problem. This 140 ft kiln required three flat cars with special blocking.

Weights big problem in large machinery

Estimating the weights of heavy pieces accurately is, naturally, difficult. And, when there is an overload, it's up to the traffic manager to make arrangements. Recently the stator, shown in Fig. 2, for a generator was estimated to weigh 453,000 pounds. The capacity of the largest car built is 400,000 pounds; and, when the blocking required for such a piece of machinery was added, the overload was 82,000 pounds. Fortunately a road bed between points was found that was in excellent condition. Even then special handling was required so that the car could move at 10 to 15 miles an hour.

Clearance is an even bigger headache than weight in shipping large machinery. Normal clearance is about 11 feet in width at the car floor height and remains the same up to a height of about 16 feet. When a machine exceeding those limitations is shipped, it is routed over roads of unusual clearance. For example, transformers like those in Fig. 3 have been sent from Milwaukee to Nashville by way of La Crosse, 400 miles out of the way.

A remarkable feat of manipulating clearances was the successful shipment of the 140 foot kiln shown in Fig. 4. It was three freight cars long, and obviously it could not bend on curves. The solution was to construct a special swivel blocking which allowed the supporting cars to make turns without throwing off the kiln. Then it had to be carefully routed over railroads that had plenty of clearance at curves so that the kiln could swing through.

The problems of shipping certain types of machinery begin to repeat themselves after a length of time, and their solutions can almost be systematized. There is some similarity from a traffic standpoint in shipping electric motors, generators, steam turbines, transformers, and engines. On the other hand, cement machinery, which is also large, presents transportation problems that are different.

Maneuvering rates

Special rates can sometimes be used to make freight savings for the consumer. "Fabrication-in-Transit" rates can be applied when raw materials come from a steel mill to the factory and then the product goes to a site. In the same way "Assembling-in-Transit" rates have been introduced to hold down, freight charges in the agricultural implement industry. This is particularly helpful where more than one factory is involved; e. g., when the parts of a tractor are made at one point and assembled at another. "Storage-in-Transit" rates are also valuable where it is necessary to store implements for a year at a point before continuing to destination.

The assembly line type of manufacturing used in making agricultural implements also has its troubles getting shipping facilities. Tractors, for example, require a trainload of empty flat cars at hand because they are run under their own power from the end of the assembly line to the waiting flat cars, which must always be there because of the lack of storage space. (See Fig. 5.)

So vast and so varied are its problems that the agricultural implement industry has its own national organization, the Farm Equipment Institute, which maintains its own traffic manager and a traffic committee composed of traffic managers from the larger farm machinery manufacturers.

Enter the truck

Meanwhile the motor truck has introduced tremendous changes in the transportation picture. The influence of the truck has grown until now truck rates, including even moving van rates, are regulated by the Interstate Commerce Commission.

For comparatively short distances this new agency appears to have distinct advantages, but also some disadvantages. Service is generally good when only one company is involved and a through run is possible. However, on long hauls it is sometimes necessary to transfer from one company to another or even to a third and fourth company. A connection may be missed; or, when a truck arrives at a transfer terminal, there already may be more freight on hand than can be handled by available equipment. Moreover, trucks must be licensed by the various states, although a few states have reciprocity laws. Hence, unusual delays frequently occur; and, when there is no equipment to handle the material, nothing can be done.

Another important point about the truck is "clearance." Often customers or field salesmen request shipment via various truck lines, without taking into consideration state laws governing widths and heights or bridge obstructions. Naturally, truck clearances are not nearly so large as railroad. Nor do the customers and salesmen always realize the chaos that would develop at the shipping platforms if shipments and trucks had to be matched because a certain truck line had been requested.

Trucks, too, have all they can do to handle their share of war-time cargoes. Moreover, there is a movement under way to restrict the length of truck hauls to a radius of 300 miles to save rubber.

Organizing for the "battle"

To help regulate the nation's transportation facilities, the Office of Defense Transportation has been set up under Joseph B. Eastman. Through it, all forms of transportation are now governed by special restrictions, the tendency being to discourage operating with less than full loads, to reduce truck mileage, and to increase efficiency.

Fig. 5 — Because assembly line manufacture of tractors calls for immediate loading, a trainload of empties must be on hand.

A number of "general orders" affect rail carriers. Box cars must be loaded to higher capacity, and cars cannot be furnished for switching service in a community where material can be delivered by truck. Shippers are required to pay freight charges on the length of car they use rather than the one they order.

Trains and trucks are not the whole problem, for war-time ship sinkings influence even traffic departments. To combat harbor congestion, a system of permits on export shipments prevents merchandise from being sent to port until a bottom is there to receive it.

The net result of these steps so far is generally adequate transportation although, of course, there are not always enough cars everywhere. Transportation men are keeping their fingers crossed.

AT RIGHT: Man and machine. In thousands of plants throughout the country this scene, repeated, is a blueprint for Axis defeat.

C-3 CARGO VESSEL

STEERING GEAR
BLOWERS

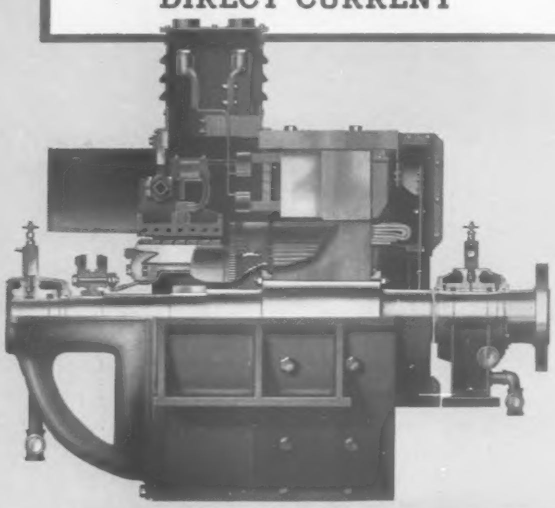
CARGO WINCHES
CARGO REFRIGERATION
VENTILATION
BILGE PUMPS

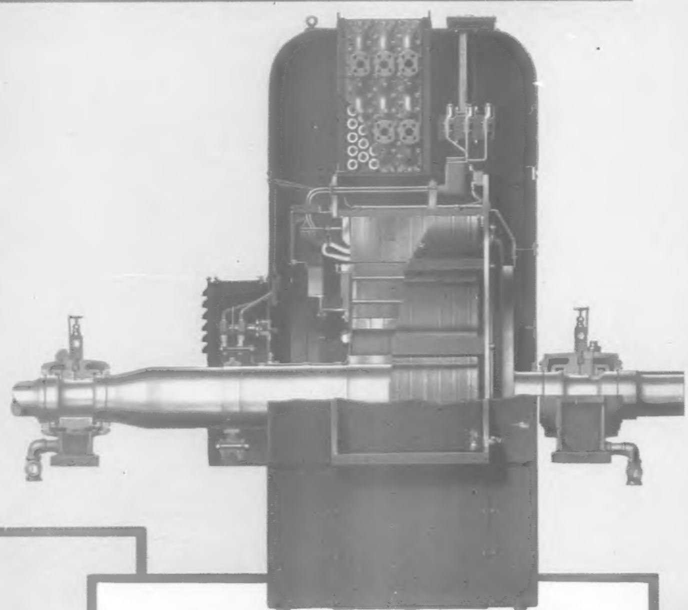
PUMPS
FORCED DRAFT FANS
COMPRESSORS
TURNING GEAR
EVAPORATORS
INTERIOR COMMUNICATION M-G SETS
MACHINE TOOLS

WINCHES
CARGO REFRIGERATION
VENTILATING FANS

CAPSTANS
ANCHOR WINDLASSES

DIRECT CURRENT



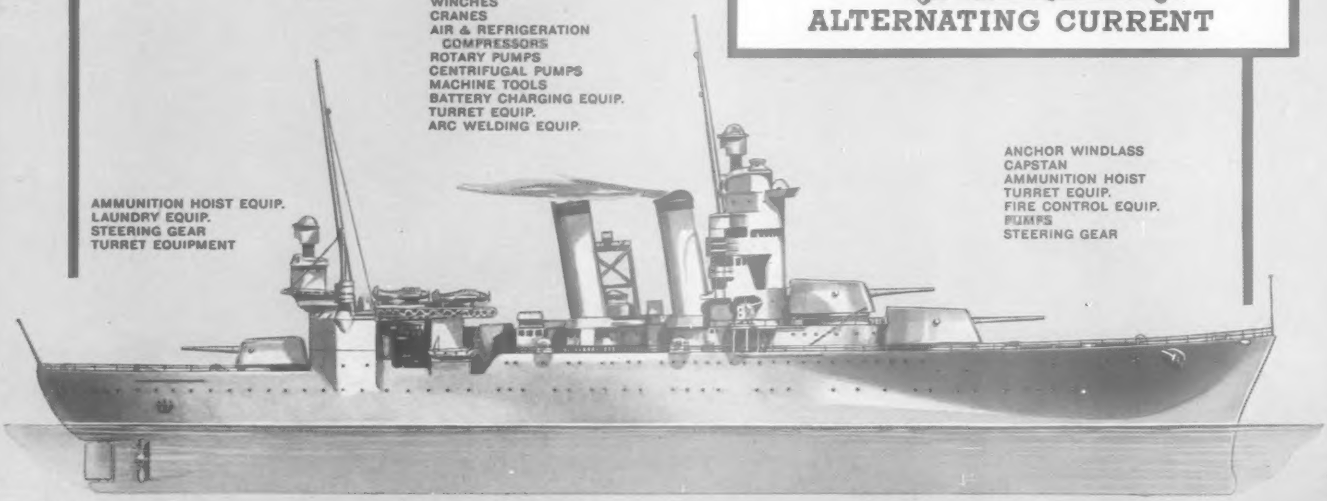


TURNING GEAR
VENTILATION EQUIP.
BOAT HOISTS
WINCHES
CRANES
AIR & REFRIGERATION COMPRESSORS
ROTARY PUMPS
CENTRIFUGAL PUMPS
MACHINE TOOLS
BATTERY CHARGING EQUIP.
TURRET EQUIP.
ARC WELDING EQUIP.

ALTERNATING CURRENT

AMMUNITION HOIST EQUIP.
LAUNDRY EQUIP.
STEERING GEAR
TURRET EQUIPMENT

ANCHOR WINDLASS
CAPSTAN
AMMUNITION HOIST
TURRET EQUIP.
FIRE CONTROL EQUIP.
PUMPS
STEERING GEAR



NAVAL CRUISER

SELECTING SHIPBOARD AUXILIARIES

Doing everything except turn the propeller, auxiliary motors and generators on warships and cargo vessels call for careful consideration. And on every front they're playing important roles in getting men and materiel into action . . . on time.

A. D. Robertson and Frank Tatum

ELECTRICAL DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

● It's 110 degrees in the shade. A husky stevedore throws in the master switch of a cargo winch, a pair of direct-current turbo-generators growl to full power, blocks creak, booms strain, and a medium tank is hoisted from the hold of the giant ship and dropped on the deck with its diesel engine purring even before the hoist tackle is dropped off. A roar, and the tank is off to battle! This same scene is repeated hundreds of times in India, Australia, Ireland, Egypt . . . wherever ships dock.

In another part of the world an alert pair of eyes spots a wisp of smoke on the horizon — sirens whine, the wake starts boiling as a sleek cruiser steps up to full speed, the interior communication system rings for battle stations, valves spin, breakers crack, rheostats are set, high-speed ammunition hoists carry heavy shells to humming turrets where huge guns punch them onward to the enemy! Another alternating-current, turbine-driven generator is pouring out power to win the war.

In enemy waters a long, black, cigar-shaped hull lies on the surface of a quiet sea. The deathly silence is disturbed only by the deep throb of powerful diesels. Power from the engine is charging banks of storage batteries which are ready at an instant's notice to be responsible for the lives of 50 men in the event of a crash dive. This direct-current generator cannot fail.

Wherever reliable power is needed, generators will be found doing their job day in and day out, whether furnishing electricity for powerful searchlights at some far-away island fortress or pumping an oil cargo in South America.

What auxiliary drive?

The first consideration in building any ship is, "How will it be propelled?" After a propulsion plant has been selected — be it geared-turbine, turbo-electric, diesel-geared, diesel-electric, or steam reciprocating engine-driven — the question of type of auxiliary power is next decided. Formerly steam was used, but modern designers prefer electrically driven auxiliaries; and today over 97 percent of all auxiliaries are powered by electric motors because electricity is so easy to handle aboard ship.

After the number of auxiliaries to be driven electrically has been determined and their power requirements calculated, it becomes necessary to choose between alternating and direct current. If the ship is for cargo service, where 60 to 75 percent of the auxiliary power is for variable speed motors, such as cargo hoists, anchor windlasses, or capstan motors, d-c equipment will get the call in spite of its higher weight and lower efficiency. However, if the ship is a fighting vessel, a passenger ship, or a tanker, with only 10 to 20 percent of its auxiliaries variable speed drives, alternating current will be used to take advantage of savings in weight, greater reliability, simpler construction, and higher efficiency.

Sometimes the main propulsion equipment will influence the selection of auxiliary generators. When a turbo-electric or diesel-electric drive is used, it may be possible to utilize the available generating capacity when the propulsion plant is not running at full power. For example, on a diesel-electric tanker with d-c propulsion, the power from the generators could be used for pumping oil or gasoline. On an ordinary tanker where the propulsion equipment is not designed for maneuverability, but a geared turbine drive is used, alternating current is called upon to furnish auxiliary power.

Generator prime mover

If the ship is diesel or reciprocating engine-powered, the prime movers for the auxiliary generators are diesel or gasoline engines. On turbo-driven ships small auxiliary turbines usually drive the generators, but in all cases the emergency generators will be engine-driven. In some cases where ships run at full power on the propeller shaft for long periods, the auxiliary generator may be driven directly from the main propulsion plant. However, additional auxiliary

Part of Motor	Type of Enclosure	Limiting Temperature Rises — Deg C			
		Class "A" Insulation		Class "B" Insulation	
		40 C Ambient Temp	50 C Ambient Temp	40 C Ambient Temp	50 C Ambient Temp
Coil windings, cores, and mechanical parts in contact with or adjacent to insulation	All except totally enclosed	50	40	70	50
	Totally enclosed	55	45	75	65
Collector rings, commutators (the class of insulation refers to insulation affected by the heat from the commutator or collector rings, which insulation is employed in the construction of the commutator or collector rings or is adjacent thereto)	All	65	55	85	75

Table I — Limiting temperatures for a-c machines

Part of Motor	Type of Enclosure	Limiting Temperature Rises — Deg C			
		Class "A" Insulation		Class "B" Insulation	
		40 C Ambient Temp	50 C Ambient Temp	40 C Ambient Temp	50 C Ambient Temp
(a) All insulated windings except item (b)	Open and semi-enclosed	50	40	70	60
	Totally enclosed	55	45	75	65
(b) Single-layer field windings with exposed uninsulated surfaces and bare copper windings	Open and semi-enclosed	60	50	80	70
	Totally enclosed	65	55	85	75
(c) Cores and mechanical parts in contact with or adjacent to insulation	Open and semi-enclosed	50	40	70	60
	Totally enclosed	55	45	75	65
(d) Commutators and collector ring	All types	65	55	85	75
(e) Bearings	Open and semi-enclosed	40	35	45	40
	Totally enclosed	45	40	50	45

Table II — Limiting temperatures for d-c machines

power will be required when in port or when operating at reduced speeds.

Large auxiliary a-c generators, if turbine-driven, operate at 3600 rpm. Small machines usually are salient pole, geared generators operating at lower speeds. Diesel-driven a-c generators run at 1200, 900, or 720 rpm.

Turbine-driven d-c generators are usually geared and, if less than 75 kw capacity, may operate at speeds up to 3600 rpm; 300 kw capacity, up to 1800 rpm; 500 kw, up to 1200 rpm; and larger machines, up to 900 rpm. Machines over 1250 kw are limited to speeds below 720 rpm. The most popular diesel-generator speeds today are 720 and 750 rpm utilizing "high-speed" engines. Gasoline engines, which are used only for small generators up to 75 kw capacity, usually operate at 1200 to 1800 rpm, while reciprocating steam engine speeds are much lower — in the neighborhood of 514 rpm.

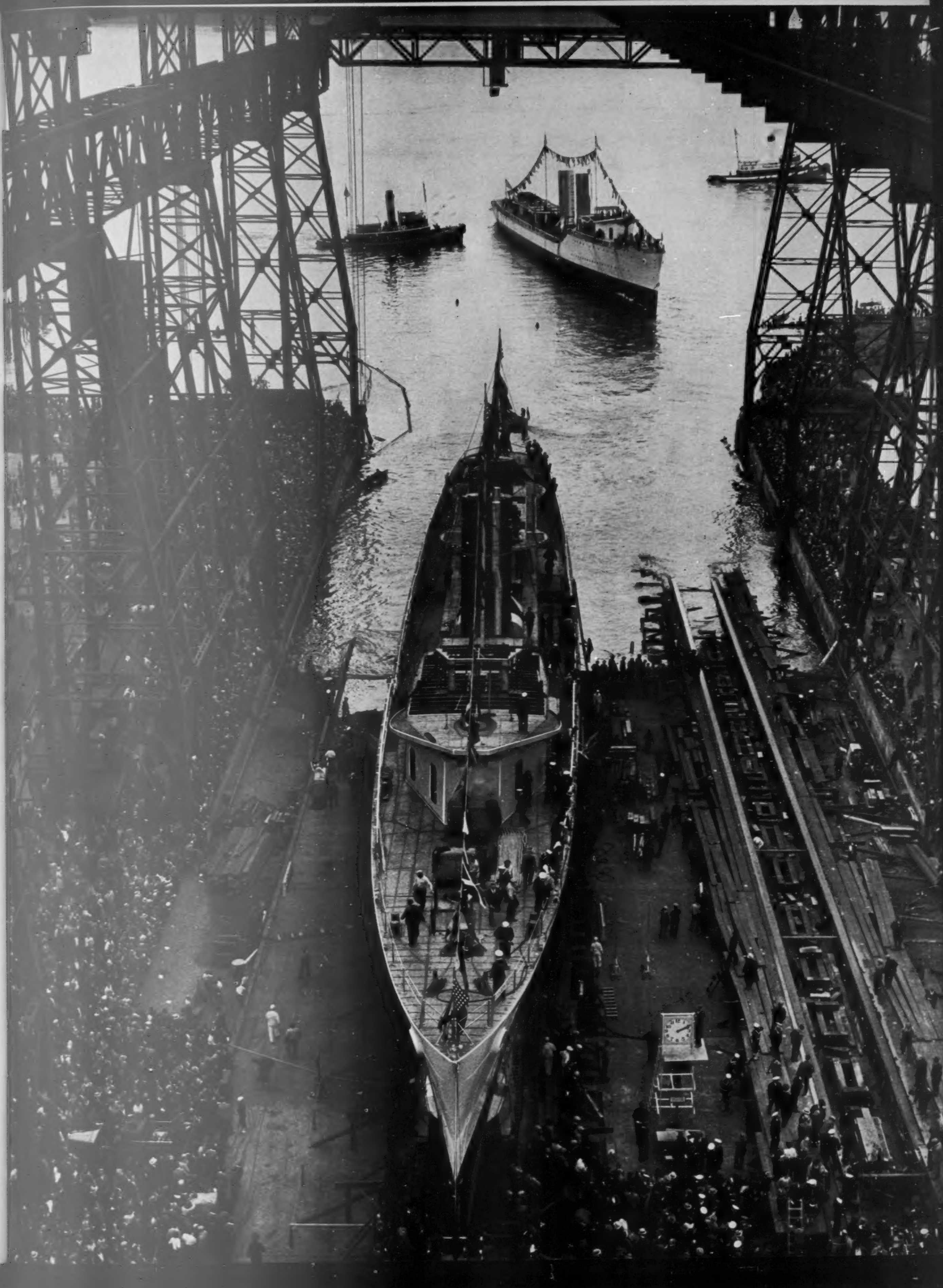
In selecting ship service generators, it is good practice to choose the higher-speed machines to save weight, materials, and man-hours required for construction. However, the maintenance requirements of the engine will increase since it is a well known fact that high-speed machines require more maintenance and are less reliable than low-speed engines.

Voltage and capacity

Generators of standard voltage at standard ratings cost less and can be delivered more quickly. In a-c generators, three-phase, 60 cycle machines are standard as in land service. A-c machines have been standardized for 230 and 450 volts, and standard ratings for 80 and 75 percent power factor are 100, 125, 150, 175, 200, 250, 300, 350, 400, 500, and 625 kva. Larger machines are used when large quantities of power are required, as on battleships, where over 10,000 kw is needed. Ordinarily multiples of these sizes are installed.

D-c generators have been developed for marine service at standard voltages of 240 volts two-wire or 120/240 volts three-wire in ratings of 50, 75, 100, 150, 200, 250, 300, 350, 400, 500, and 600 kw. As in a-c generators, the tendency is to use additional generators of these sizes where more power is required.

AT RIGHT: Launchings like this, going on every day, add up to history's greatest shipbuilding program. (H. M. Lambert photo)



A class C1-A cargo vessel ready for service. Most ships of this type use direct current for auxiliary motors and generators.

Insulation

The ambient temperature in a ship's engine room approaches 50 C. Therefore, for a d-c generator using class "A" insulation, a 40 C rise is permissible, with a 55 C rise allowed when it is overloaded 25 percent for the two hours. Class "B" insulated machines are permitted a 60 C rise. Temperature rises permitted by AIEE rule No. 45 and other marine standards are shown in Tables I and II for a-c and d-c machines, respectively.

The trend in insulation is toward higher operating temperatures and the use of either air or water coolers. At the present time considerable research is being carried on in an effort to reduce substantially the physical size of generators using the higher temperatures permitted by improved insulation and varnishes.

Mechanical construction

The mechanical construction of a generator depends upon three factors:

(1) Type of machine and duty cycle

(2) Location of generator in machinery space

(3) Prime mover of generator.

Generators of continuous duty rating and high temperature rises, located in crowded machinery spaces close to boilers, piping, and ventilating ducts, are usually totally enclosed with surface coolers and


Auxiliary turbo-generators, like this 250 kw unit, provide power for everything except propulsion aboard cargo vessels.

Powerful, sea-going commercial tug, equipped with d-c auxiliaries and driven by diesel engines, requires 30 kw for auxiliary power.

A 24 kw, 120 volt, 375/750 rpm, d-c exciter, with end-cover removed, is direct-connected to the generator shaft of a tug.

a recirculating air system. Water coolers are of the double-tube type to prevent any possibility of water getting into the machine and circulating through the generator. The coolers used are large enough to keep the air entering the machine at 40 C, thus carrying off in the water heat from the generator and leaving the engine room cool. The closed air circulating system keeps foreign matter in the engine room air out of the windings. Where the machinery space is not crowded, generator sets are located on upper levels, and drip-proof, fully protected machines are used. However, considerable difficulty has been experienced when open type, drip-proof machines are located near ventilating ducts where grit particles and cinders are blown through the above-deck ventilating duct into the engine room and deposited on the generator windings and commutators.

Open generators are never used in the engine room of a ship because drops of water are constantly condensing on overhead piping. Drip-proof covers are installed on machines so that water coming from an angle less than 15 degrees will not fall into the machine or run in on exposed parts. Totally enclosed and drip-proof machines are more expensive and often heavier than open machines, but their maintenance is less and their reliability greater.

The prime mover determines the internal construction of a generator, especially the rotor or armature. A diesel engine-driven generator will require a large shaft, and press fits must be heavy because torsional vibration is transmitted from the engine. A turbine gives a smooth flow of power; hence the shaft of a turbo-generator can be smaller. If reduction gears are used between the turbine and the generator, the vibration and torsional problems are further reduced.

Commutator end of a 100 kw, 120/240 volt, 1200 rpm, d-c marine type auxiliary generator without drip-proof covers.

This naval tug goes right out to sea with the fleet, is powerful enough to haul back any type of warship that may be disabled.

Ball and sleeve bearings for marine generators

Marine generator bearings must be completely accessible. Sleeve bearings are usually mounted in split housings to permit removal of the bearing bushings without disturbing the rotor or armature of the generator. Anti-friction bearings have found their place in marine generators for many ratings up to 800 kw at 750 rpm. However, most marine engineers believe that more reliable operation can be had from generators of 100 kw and above with sleeve bearings.

Sleeve bearings are generally force-feed lubricated from the prime mover oil pump. Oil is supplied at 30 to 40 pounds pressure and reduced to a gravity flow over the bearings by a needle valve at the top of the bearings. In some of the small ratings, ring oiling of sleeve bearings for marine use has been perfected, using guides to prevent rings from sticking as the ship pitches and rolls. Either cup or pressure gun fittings are used with anti-friction bearings. A pressure release prevents grease from being forced into the windings.

Housings, frames, brackets, stators

When generators are placed in crowded machinery rooms, accessibility becomes a problem. To give greater accessibility on a-c and d-c machines larger than 100 kw, the yokes as well as the housings or bearing brackets are split so that the armatures can be removed easily. On salient pole a-c machines stator shift is used to provide access to the winding where the extra length is permissible.

Present-day "high-shock" requirements of commercial and fighting ships prohibit the use of cast iron and die cast material. To eliminate these items, cast steel is used almost exclusively. Structures welded from rolled steel are also taking the place of steel and iron castings since they are lighter and present a modern, streamlined appearance.

Bearing pedestals are split at the shaft centerline and designed with a removable bearing bushing. Short and narrow pedestals are used in order to conserve weight because new developments permit higher bearing loadings with thinner babbitt. Sometimes it is specified that the machine must run without scrapping its rotor or armature even after the babbitt has

been wiped from the bearings and the shaft is running on the bearing bushings.

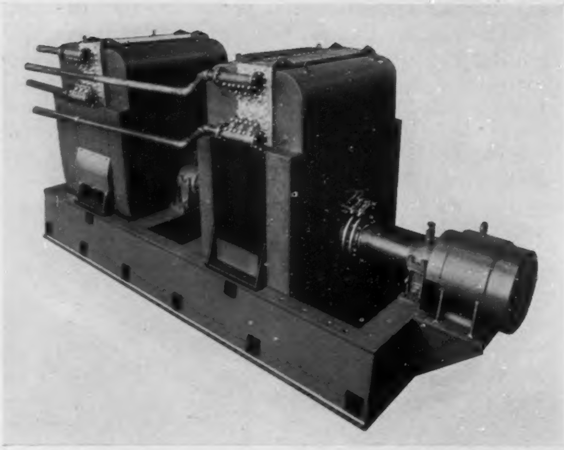
Corrodable fittings

Small parts of generators on vessels for salt water service, such as springs, brush holder studs, nuts, bolts, pins, terminals, and screws, are made either plated or of corrosion-resistant material to prevent damage from corrosion. Cadmium, zinc, or silver plating is used on parts which cannot be painted. The windings of a marine machine have a special insulating varnish. The coils are given an extra dipping and baking to insure a high resistance to water and oil particles in the air.

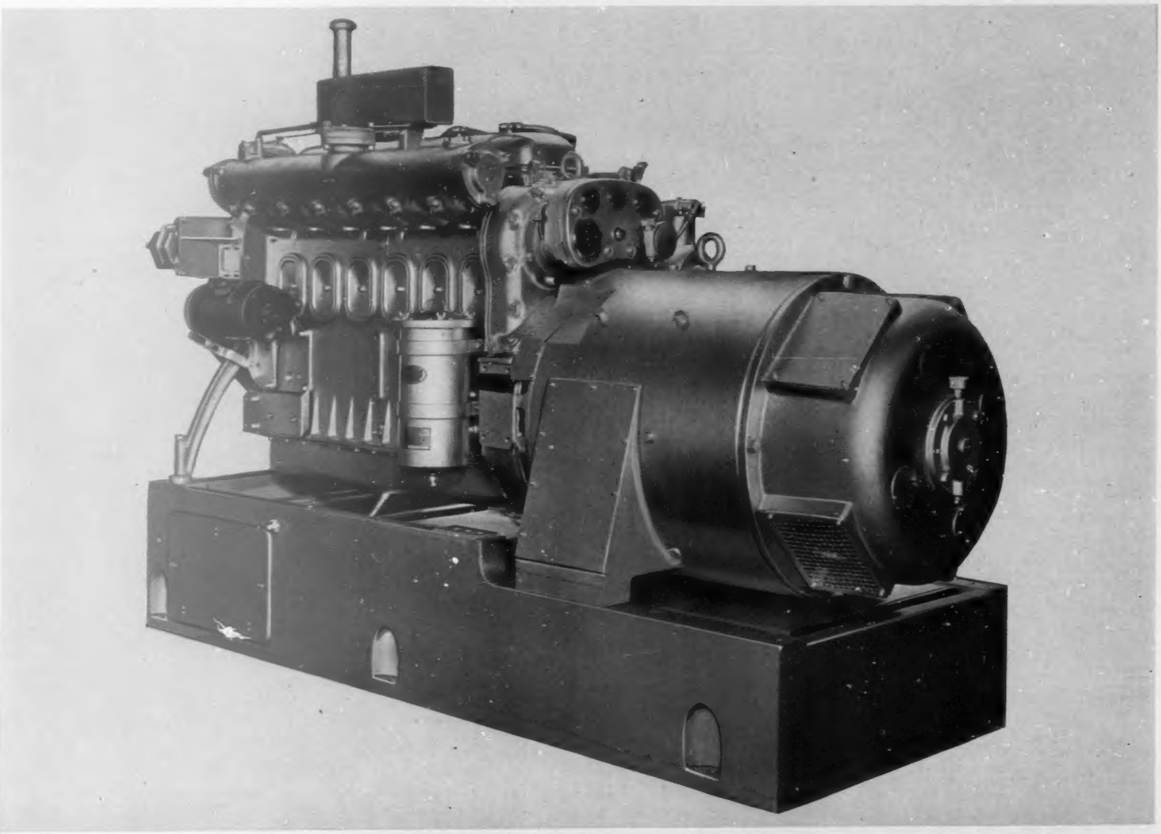
Miscellaneous considerations for auxiliary generation

It is advantageous to have shipboard d-c machines designed for 240 volts since money and weight will be saved with the higher voltage auxiliaries. However, lighting and cooking, as well as interior communication, require a 120 volt power source. Slip rings and a balance coil good for 25 percent unbalance installed in conjunction with the d-c generator represent an economical way of getting the 120 volt current. However, when the requirement for 120 volt power is less than 10 percent of the total generator output, a separate motor-generator set, with a 230 volt d-c motor driving a 115 volt generator, is more economical.

To conserve weight and space three-wire marine generators usually have two slip rings and a two-legged balance coil instead of the three rings and a three-legged balance coil.



Supplying a-c power to an arc furnace used for repairs on a sub-tender, this special duty m-g set is rated 850 kw.



Auxiliary d-c fleet tug generator, rated 60 kw, 120 volts, 1200 rpm, is driven by a diesel engine, has all steel parts.

Rheostats and field discharge resistors furnished with the generators are designed and manufactured to meet present-day requirements for shock and are usually mounted on the back of a dead-front switchboard.

Tables III and IV list spare parts for a-c and d-c machines, respectively. They have been subdivided into spares for a commercial or cargo ship and spares for a passenger or fighting ship.

Each marine power generator presents its own special problems, such as fire extinguishing systems, terminal arrangements, mounting of temperature detectors, foot height, mounting holes, type of coupling, bearing relays, etc., and there are few general rules that can be laid down for this equipment.

Spare Parts	Number of spares per vessel					
	Commercial or cargo vessels	Passenger or fighting ships — No. of generators per ship				
		1	2	3	4	5
Bearings or bearing liners	1	1	1	1	1	1
Oil gauges for sleeve bearings	—	1	1	1	1	1
Brushes, collector ring, sets	1	2	3	3	4	4
Brush rigging insulation, sets	1	1	1	1	1	1
Brush holders, collector ring, with springs	1	1	1	1	1	2
Brush holder springs	3	2	3	3	3	4
Bearing lubricant seals, sets	—	1	2	3	3	4
Bearing removal tools	—	1	1	1	1	1

Table III — Spare parts for a-c generators

Spare Parts	Number of spares per vessel					
	Commercial or cargo vessels	Passenger or fighting ships — No. of generators per ship				
		1	2	3	4	5
Bearings or bearing lines, sets	1	1	1	1	1	1
Oil gauges (for sleeve bearings)	—	1	1	1	1	1
Commutator brushes, sets	1	2	3	4	4	5
Slip ring brushes, sets	1	2	3	3	4	4
Commutator brush rigging insulation, sets	1	1	1	1	1	1
Slip ring brush rigging insulation, sets	1	1	1	1	1	1
Commutator brush holders, complete with springs	1	1	1	1	1	2
Slip ring brush holders, complete with springs	1	1	1	1	1	2
Commutator brush holder springs	3	2	3	3	3	4
Slip ring brush holder springs	3	2	3	3	3	4
Bearing lubricant seals, sets	—	1	2	3	3	4
Bearing removal tools	—	1	1	1	1	1
Field coils, each size and type	1	1	1	1	1	1
Armature, complete	1	—	—	—	—	—

Table IV — Spare parts for d-c generators

Forced-Oil Cooled Power Transformers

Vitally needed increases in power transformer capacities can now be obtained quickly with a new system of forced-oil cooling that saves 25% in critical war materials on new transformers. The new cooling unit, called the "Electro-Cooler," will step up capacity of transformers already in service about 20 to 60%.

The forced-oil system of cooling transformers is made highly practical with the "Electro-Cooler," because the unit is compact, factory-assembled and factory-tested at high pressure to minimize maintenance.

It consists of a radiator-type cooler and a special pump with motor enclosed, connected by piping to standard radiator valves at the side of the transformer. No stuffing boxes are required in the special pump; the motor is self-cooled and self-lubricated.

A wartime development designed to save copper and steel, the "Electro-Cooler" is expected to have wide use in post-war applications also. For the current emergency, it can not only be built into new transformers, but can be readily applied to transformers already in service, subject to the recommendations of the transformer manufacturer. If the transformers are equipped with the conventional type radiator valves, installation can be made in three to four hours without even removing the oil in the transformer.

New Alternating Current Welder

A new alternating current welder, operating on a perfect electrical circuit that produces the proper voltage for every current setting, has just been developed. It is designed to increase the efficiency and step up the speed of welding heavier, thicker metals. In the new welder the transformer and reactor are built as an integral unit. The reactor coils surround the air gap, eliminating magnetic leakage.

This arrangement provides continuous control from 35 to 250 amperes, a safe, high, open circuit voltage at low current, where a-c welding was previously most difficult, and a lower open circuit voltage at higher current where efficiency and power factor are all-important. An ideal electrical circuit results, striking characteristics are improved and size and weight of the unit are reduced.

The new welder is built without plugs, taps or switches of any kind. Manual control at the top of the unit covers the entire welding range from maximum to minimum setting with less than a dozen turns of the control handle. Units are available up to 600 ampere capacity.

For further, more detailed information regarding these new products, write the Editors of ELECTRICAL REVIEW.

HOW TO SAVE COPPER AND MAN-HOURS

WITH ALLIS-CHALMERS 5/8% STEP REGULATORS!

One Midwestern System Conserves Copper and Man-Hours . . . Maintains Uniformly High Voltage . . . By Installing an Allis-Chalmers 5/8% Step Regulator!

To maintain maximum production in the nation's industrial plants, utilities must not only meet the growing demand for power — they must supply this power at uniformly high voltages.

But when line loads grow heavier, voltage tends to drop . . . as it did on this midwestern system . . .

At the end of a 20 mile feeder, motors were operating at only 88% of rated voltage. To correct this condition and allow for anticipated load growth required replacing the three No. 4 solid conductors with No. 2 copper wire.

Or there was needed $\frac{5280 \times 20 \times 3 \times 200.5}{1000}$ = 63,360 lb of copper.

Crediting the salvage of the No. 4 wire (39,920 lb), the additional copper needed was 23,440 lb. Also, thousands of man-hours were required to remove the old conductors and install the new.

But, before going ahead, this system called in an Allis-Chalmers engineer. He showed them how they could correct the voltage condition by installing a 104 kva, three-phase, 12,000 volt, Allis-Chalmers 5/8% Step Regulator.

The regulator required but a few hundred pounds of copper, a fraction of the man hours to build and install. What's more, it corrected for reactance as well as resistance drop . . . compensated for fluctuating source voltage.

Before you buy a regulator, remember only Allis-Chalmers 5/8% Step Regulators give you all the five advanced engineering features listed on this page!

For all the facts on how Allis-Chalmers 5/8% Step Regulators give you *on-the-line* performance, call the district office near you. Or write to Allis-Chalmers, Milwaukee, Wisconsin . . . *today!*

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SYSTEMS ALL OVER THE COUNTRY find Allis-Chalmers 5/8% Step Regulators, like this one, invaluable in maintaining uniformly high voltage under constantly growing loads.

REASONS WHY ENGINEERS CHOOSE ALLIS-CHALMERS 5/8% STEP REGULATORS!

1. **Closer Regulation!** 5/8% half-cycling steps plus "Feather-Touch Control" permit band width settings within ±5/8 of 1%.
2. **Longer Contact Life!** Not a single contact has ever been replaced on an Allis-Chalmers Regulator due to deterioration under normal operation.
3. **Lower Exciting Current!** Need only 1/3 the exciting kva required by older types of regulators.
4. **Increased Dielectric Strength!** Unit construction eliminates 78 bolted connections between compartments.
5. **Minimum Maintenance!** No holding or braking devices. Complete oil-immersion of all moving parts means there's nothing to lubricate.

When On-the-Line Performance Counts... Count On

ALLIS-CHALMERS

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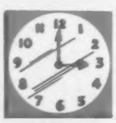
MORE POWER in a hurry!

For Fast, Sound Industrial Expansion or Conversion Choose Allis-Chalmers Dry Type Transformers, and Get Better Machine Performance While You Conserve Copper!

More power in a hurry! That's what industries all over the country need today. And that's what you get when you install Allis-Chalmers Dry Type Distribution Transformers for load center power distribution . . .

WITH A 6-WAY SAVING!

1. You save time by eliminating the necessity of building fire-proof vaults.

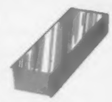


2. You save floor space because Allis-Chalmers Dry Type Transformers can be mounted anywhere — on a beam, on a post or on an overhead platform — with no danger of oil leaks.

3. You save man-hours! Smaller transformers permit changeovers to be made quickly, easily.

4. You save vital power! Load center location means less voltage regulation . . . lower line losses . . . improved performance from motors and lamps.

5. You save copper! Long runs of heavy secondary copper are not needed. You can conserve as much as 50% of this vital material.



6. You save on maintenance! No insulating liquid to handle, test or filter. Your servicemen's time can be utilized on more important jobs.

This six-way saving is important to you. And it's important to your country! Get all the facts from the district office engineer near you. Or write Allis-Chalmers, Milwaukee, Wisconsin.

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